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# FIORDS.

BY

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INTRODUCTION.—ON THE SCOPE AND MEANING OF THE TERM.—*Fiord* is borrowed into English from the present Norwegian *fjord*, which has developed from an earlier form, in* Old Norse *fjordr*, and is now applied to the long, narrow, deep arms of the sea which occupy the distal portion of deep, steep-walled, rock channels on the western coast of Norway. The English word *forth* and the Scottish *firth*, applied to quite similar embayments in different parts of the British Isles, also the English verbs *fare* and *ferry*, have developed from the same root. The primitive Indo-European root $\sqrt{\textit{par}}$, from which these several words have sprung, has, in general, the meaning of "motion forward," "passing over" and then "to travel." Possibly the word in its early form was given to the fiords from the fact that the settlers along the sides of the fiord found it nearer to go across than to go around. A significant fact comes out here in relation to Norway's commerce and her coast. Fifty-three per cent. of the boundary is water, and forty-seven per cent. is land where the country backs up to Sweden; but ninety-five per cent. of all Norway's export trade goes out over the water boundary. No wonder the idea of travel and crossing over is in the name given to fiords.

The derivation of the word is quite certain, but the present meaning is in some confusion. This confusion has arisen from three sources—

(*a*) The term has been used both in a technical and in a popular sense. This is legitimate, and may be continued, as is done with multitudes of scientific words.

(*b*) It has been used with three distinct meanings—1st, embracing only the water; 2nd, including both water and containing walls; and 3rd, the walls only.

(*c*) Fiords, like other physiographic types, grade into related forms bearing different names. This source of confusion cannot be avoided; but the perplexity can be overcome in part by recognising its source. Many of our terms do not admit of exact limitations at present, and others which might be so limited never have been.

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* I am indebted to Prof. W. H. Schofield of Harvard for these notes on derivation.

Examples of the three types of definition for *fiord* follow. Penck* illustrates the first:

> Typical examples are long, slender, much-branched bays which extend inland often over 100 km.

Geikie† uses the second type:

> A fiord is a long, narrow, and often singularly deep inlet of the sea which terminates inland at the mouth of a glen or valley. . .No line of demarkation can be traced between the water-covered portion and that beneath the sky.

Here the author starts with a definition of the first type; but the closing sentence and the context show that he really holds the view of the second type. LeConte‡ employs the third type:

> Fiords, then, are deeply-eroded land valleys—usually half-submerged glacial valleys.

These quotations are merely types of classes. Each type could be duplicated several times, and occasionally two types can be found in the same book.

The dictionary study of the word has revealed an interesting series of definitions. From Webster's editions, beginning with a small book and passing through a series increasing in size and comprehensiveness, the following were taken:

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|---|---|
| Webster's Abridged: | Fiord, an arm of the sea; a bay. |
| “ Condensed: | “ a bay or inlet with high banks. |
| “ Academic: | “ a narrow inlet of the sea between high rocks. |
| “ Collegiate: | “ a narrow inlet of the sea between high “ banks or rocks. |
| “ International: | “ a long, narrow inlet of the sea having precipitous walls. |

Not one of these definitions defines sufficiently to exclude embayments, which are never considered to be fiords; nor do they call attention to several of the essential characteristics of fiords.

Worcester's Comprehensive Dictionary gives, as equivalent to fiord, these terms:

> (*a*) Firth; (*b*) a rock-bound strait; (*c*) a frith; (*d*) a strait of the sea; (*e*) an estuary.

What idea of a fiord will a student get from any or all of these definitions? And yet why condemn the dictionary? How can a lexicographer be expected to be able to define a scientific term which specialists have failed to delimit? It seems plain that the best way to establish a clear definition of *fiord* is to observe carefully forms acknowledged by all to be fiords, to note all their common features, and from these to deduce a definition. Then, by comparison, related forms and those so ill-defined by nature as to be questionable can be put where they belong.

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* Morph. der Erdoberfläche, 1894, II, 563.

† Textbook of Geology, 1893, 291.

‡ Elements of Geology, 1891, 574.

## SECTION I—A DISCUSSION OF THE CHARACTERISTICS OF FIORDS.

Fiords are features of the coast of Norway. This all will grant. Greenland, especially on the western side, has fiords; northwest Scotland and northeast Labrador also have them. Features common to fiords of all these regions will certainly be accepted by everyone as fiord characteristics. An arm of the sea lying in a channel of peculiar form, then, is a fiord, and it becomes our task to describe this channel and to discuss its relation to the water. Both where occupied by the water and inland from the head of the water this channel is broadly U-shaped, or trough-shaped, comparatively uniform in width, and often nearly straight. The ratio of length to breadth of the water-covered portion varies. An average is about 30:1. This portion is frequently 75–100 miles long. The water may occupy only the outer portion of the channel, or may extend over a half, or even all of it; in the latter case sometimes terminating in a cirque. The channel is always deep, and the water within is of considerable depth, frequently exceeding several times that of the foresea at the mouth, and equalling one-half the average width.

Steep, smoothed walls of bare rock are features very striking and constant. The slope of the wall suffers no change at the water's edge, but continues steep to the bottom. It may be of nearly the same steepness from summit to base, or the descent may be in huge steps, or with a steep section in the upper part and a gentler slope towards the bottom, or the reverse. One may frequently sail along a fiord an hour or more without finding a possible landing, so precipitous and continuous are the walls. The average inclination of the walls of the fiords of Europe has been given as 35°. This, of course, includes many of much lower angle than the more typical ones. In order better to realize the steepness even of this angle, recall the fact that skilled mountain-climbers consider an ascent of 37° scarcely climbable unless it be clothed with vegetation. The channel walls are usually sub-parallel and nearly straight, and the straightening and smoothing seems to be the result of recent changes. There are marked differences between the fiord channel and the valley of a stream. In the sub-mature river valley, in strong relief, spurs run out into it some distance, standing as buttresses against the walls; and in young valleys, as seen looking up or down stream, the spurs seem even to overlap, entering alternately from one side and then from the other. But in a fiord channel such spurs are of rare occurrence. The appearance is rather that the spurs have been brushed off, leaving a steep wall.

The floor of a fiord is somewhat uneven. It does not have a continuous slope from the head seaward, but it may be very far below the surface of the water in the middle part, and near the surface toward or at the mouth, thus making a great, much-elongated basin. It frequently happens that beneath a single fiord there are two or several of these basins separated by sills or swells where the floor approaches the surface. Transversely, each depression is broadly U-shaped, or trough-shaped, with steep descents on either side and a very low gradient across the bottom. Longitudinally, the elongated depression gradually shallows from the maximum depth toward either end. The floor gradient, local as well as average, is greater seaward than landward. In Sögne Fiord, Norway, the mean floor gradient from the deepest part to the mouth is 62 minutes; from the same depth to the head it is 39 minutes. A mean floor slope for an entire fiord of 6° to 7° is very rare, but for individual basins slopes may often be much more. Little regularity of form exists among the depressions or basins.

As mentioned above, sills transverse to the channel rise between the basins in a very peculiar manner. A few soundings from Sögne Fiord and others will show something of their form. At the mouth of Sögne the floor rises in a sill until the water is but 180 metres deep above it; while the maximum depth several miles inland is 1,242 metres. Loch Hourn, Scotland, has four basins, whose depths are respectively 18m., 49m., 38m., and 49m., while the sills between them lie beneath from 1 to 13m. of water. The freshness of the surface water and the constancy of the water temperatures in the basins at all seasons of the year are good evidences that the sills form barriers completely across the channel. In many cases the sills are known to be of bare bed-rock; while in some, as at Loch Hourn, they are known to be covered with deposits of loose material. As a rule the channel widens where the sill occurs, and narrows in the deepest places. Many fiords become much deeper where they receive a considerable tributary. In the bends of fiords the deepest part of the channel is not in the centre, but is near the outside of the curve.

The channel in which the fiord lies usually extends some distance landward beyond the head of the fiord and rises to the level of the highlands in the interior. The floor and walls show no change of character at the end of the fiord, but the floor rises by more steep and less steep reaches, or by huge steps, with basins on the tread, or by a gentle incline, with swells rising occasionally transverse to the channel; while the walls continue unchanged in their main features. They are steep, sub-parallel, smoothed and scratched as in the part of the channel occupied by the water. Lakes often lie behind the swells in this upper part of the channel, like a row of shining beads, sometimes several on one string. By the overflow of the lake the sill is sometimes cut through, exposing a section. Usually the sill, thus exposed, is of firm bedrock, but occasionally it is of drift.

Many lakes, having similar rock basins of great depth, and walls like those of fiords, occur on the eastern slope of the Scandinavian mountains. These lakes and their associated channels are so strikingly like the fiord channels on the western side of the mountains that one writer has enthusiastically remarked:

> The Swedish slope of these mountains would become a fiord coast if the piedmont were covered by the sea.

Likewise, if the sea washed the eastern slopes of the mountains of New Zealand, of the southern Andes, and of the Scottish Highlands each region would possess a fiord coast. This is equally true of the slopes of the Alps. Nordenskjöld* says that most fiords and up-valley lakes have rock basins. If these channels containing lakes, and those without lakes, but in the fiord and lake regions, were occupied with water, they would be as much fiord channels as any along the present coast.

The upper parts of many fiord channels in Greenland, Norway, and Alaska are at present occupied by ice tongues, some reaching to the water's edge and, as Russell thinks, far out into deep water, but creeping on the bottom because too thick to be floated.

The fiord channel not only extends landward beyond the head of the fiord, but sometimes leads out across the continental shelf a considerable distance. Here, too, it maintains the uneven floor as in other parts. There is usually a very marked rise of the floor to form a sill across the entrance to the fiord. Fiord channels are sometimes connected, especially in the distal portion, by cross-channels. These, when occupied by water, make cross-straits, called sounds in Norway, and partake of the nature of the fiord in every way, but are never deeper than the fiord. Where their number is great the number of off-shore islands is great, and the latter form an island belt or zone of large and small rocky islands, arranged in no apparent order. The outer mouth of the fiord lies at the seaward margin of this belt, and the inner mouth at the landward edge of it. This belt or field of islands, called in Norway *Skjaergaard*, is more fully developed along coasts of weak relief.

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* Bulletin Geol. Inst. Upsala, 1899, 4, 220.

Many lateral streams which enter fiord channels do so from discordant high-level waterways—*i. e.*, they come in high up on the walls of the master channel, giving the impression that the latter had been cut much deeper than the former. For these lateral channels, with high-level discharge, Gilbert has proposed the name of *hanging valleys*. Their waters descend by steep rapids, or by a series of cascades, and occasionally by taking one grand leap from a height of several hundred feet to the fiord below, clearing the wall in such a manner that boats can pass between the falling water and the rock. The discordance of the side-valley floors with the master channel floors is a very constant feature in fiord regions. Sometimes the former is many hundreds of feet above the surface of the fiord, sometimes it is below ; but even then soundings may show that if the water were withdrawn from both, the lateral would appear as a hanging valley with reference to the main channel. Near the mouths of fiords some of these high-level side channels lead downward away from, instead of towards, the master, which is a strikingly peculiar feature. Observation goes to show that this is not at all uncommon along coasts possessing fiords. They have the appearance of distributary channels, and may be so called. Any theory for the origin of fiords must take into account these relations of side streams and valleys in order to explain the fiords. Several other characteristics have been noted by different authors; but they prove to be rather uncommon than common, hence cannot be called characteristics. Among them may be mentioned a tendency of fiords in some regions to be sub-parallel to each other and at right angles to the coast.

## SUMMARY.

From the preceding paragraphs it may be seen that certain features of fiords and their channels are much more constant than others; many features vary in form, others are sometimes wanting. The more constant ones, then, may be called the essential features, and the others variable or secondary features. (*a*) The inequality in the relief of the channel floor is constant; but the form of the basin, the number of basins and swells in one fiord, and the depth of the water over the sills, are all points which may vary. (*b*) The walls are of rock, high, steep, and smoothed; but the degree of steepness and smoothness and the height vary through a wide range. (*c*) The channel continues landward from the head of the fiord comparatively unchanged; but it may extend a long or short distance; it may or may not contain fresh-water lakes or an ice-tongue. (*d*) Commonly, the channel does not extend out beneath the foresea, but is closed by a swell. (*e*) High-level lateral valleys pouring their streams into the fiord over the edge of the fiord walls or through a high notch are constant peculiarities; but these hanging valleys may vary in height from a few thousand feet above the surface of the fiord to some distance below the surface. Toward the mouth of the fiord the high-level branches may lead away from the master as if they were distributary channels. (*f*) Sounds or straits and islands occur along the shores of fiord coasts. They may be many or few, small or great. (*g*) Parallelism of fiords and their direction relative to the coast are features much modified by the regional topography and rock resistance; hence they cannot be emphasized as characteristics.

As a conclusion to this section are presented three forms of a definition for the word "fiord." It is hoped that they will be sufficiently substantiated by this and other descriptions to give them general acceptance. Each conforms in length to the usage of a recent, established type of dictionary:

COMMON SCHOOL SIZE: Fiord, a long, deep, uneven-floored arm of the sea.

ACADEMIC SIZE: Fiord, a long, deep, uneven-floored arm of the sea, entering a region of strong relief.

UNABRIDGED SIZE: Fiord, a long, deep arm of the sea, occupying a portion of a channel having high steep walls, a bottom made uneven by basins and sills, and with side streams entering from high-level valleys by cascades or steep rapids.

## SECTION II—ON FIORD REGIONS AS A TYPE OF COAST: A COMPARATIVE STUDY.

Besides Norway, Scotland, Greenland, and Labrador several other regions furnish excellent examples of fiords, among which are western British America and southern Alaska, the Chilian coast, South Island of New Zealand, and many islands in each polar region. The coast of Maine and most of the land bordering the Baltic Sea and its entrance have fiord-like forms which depart materially from the typical examples previously described.

Berghaus* and others have studied these regions as types of coast, and have mapped them under two or three distinct types.

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* Physical Atlas, 1892, Map 19.

In Maine the relief is weak; the embayments are not bounded by steep, high, sub-parallel walls, but by gently rising walls of moderate height, which contain between them an inlet rapidly widening seaward. The maximum difference of floor relief is not over 30m., but there are often distinct basins and sills. In the Baltic Sea and along Denmark coasts are many embayments differing locally from each other, and as a group, from the fiords of Norway, and yet presenting so many similarities that some authors class them as fiords, while others, more conservative, call them fiord-like features. The names *fiärden*, *shären*, and *föhrden* have been given to them, each for a distinct type of form. The first term is applied to embayments in regions where there are few islands, and *shären* is used for the passages and straits where the coast is much dissected, hence abounding in islands and rock reefs, but with very few embayments. Any map on sufficiently large scale will help to locate the regions having each type. The embayments called *fiärden* are narrow, tortuous sea arms, with some shallow basins, best developed where up-valley lakes intercept the sediments. Channels in both *fiärden* and *shären* types are not deep; the walls are low and rise at a small angle. The relief of the lands is weak, only a few hundred feet where strongest, usually much less. Weak relief of lands and little depth of water seem to go together. The *föhrden* type of embayment occurs on the eastern coast of Denmark, and along the coast of Sweden near Cimbrishamn. The relief of the land is weak, and the water in the channels is shallow. The form of the embayment varies much. Some are narrow and intersect, forming a net; some are very tortuous, and others are sack-shaped, broad within and constricted at the mouth. Local depressions or basins occur in some of these bays, and in one or two cases a sill is known at the entrance. Since a good ship channel goes to the head of the inlet, and the water is not too deep for easy anchorage, while the walls are not so steep as to interfere with landing, *föhrden* make excellent harbours.

The relation of these three forms to typical fiords has been generally overlooked. The most pronounced differences between the true fiord and the fiord-like forms are in the height and steepness of the walls and in the depth of the water in the channels—differences probably due to the weakness of relief on the coasts exhibiting the fiord-like types. The next section will give additional material on the forms.

(*To be continued.*)